

NBSIR 73-229

30

Interim Report No. 6. Corrosion and Creep Testing of Coated Reinforcing Bars in Concrete

Nonmetallic Coatings for Concrete Reinforcing Bars

James R. Clifton, Hugh F. Beeghly, Erik Anderson, Robert G. Mathey

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

April 1973

Interim Report for Period January – March 1973

Prepared for
Federal Highway Administration
U. S. Department of Transportation
Washington, D. C. 20590

**INTERIM REPORT NO. 6. CORROSION AND
CREEP TESTING OF COATED REINFORCING
BARS IN CONCRETE**

**NONMETALLIC COATINGS FOR CONCRETE
REINFORCING BARS**

James R. Clifton, Hugh F. Beeghly, Erik Anderson, Robert G. Mathey

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

April 1973

Interim Report for Period January – March 1973

Prepared for
Federal Highway Administration
U. S. Department of Transportation
Washington, D. C. 20590



U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

ABSTRACT

The possibilities of protecting steel reinforcing bars embedded in concrete from corrosion by using organic barrier-type coatings are being investigated in this project. This corrosion is accelerated by the chloride ions of the two most commonly used deicing materials, calcium chloride and sodium chloride.

In this report, corrosion studies carried out on coated reinforcing bars embedded in concrete are discussed. Methods of instrumenting creep-test specimens are also explained.

The electrical potentials of coated reinforcing bars are not reliable indicators of the corrosion state of the steel bars. The electrical resistances of the coating films are more reliable indicators of the performance of a coating material than the electrical potential measurements.

Key Words: Corrosion; creep testing; epoxy coatings; poly(vinyl)chlorides; strain gages; steel reinforcing bars

CONTENTS

	<u>Page</u>
1. Project Information.....	1
2. Introduction.....	1
2.1 Background.....	1
2.2 Objectives.....	1
3. Discussion of Activities.....	2
3.1 Corrosion Studies of Coated Reinforcing Bars Embedded in Concrete.....	2
3.1.1 Materials and Fabrication of Test Specimens.....	2
3.1.2 Corrosion Test Methods.....	4
3.1.3 Results and Discussion.....	5
3.2 Creep Tests.....	6
3.2.1 Calibration of Springs.....	6
3.2.2 Strain Gages.....	7
3.3 Implementation.....	7
3.4 Talks Based on Project.....	8
3.5 Meetings Attended.....	8
3.5.1 Meetings Attended in Conjunction with the Project.....	8
3.5.2 Pertinent Meetings Held Between NBS Staff and Industrial Representatives.....	8
4. Status of Project.....	9
5. Problems.....	9
6. Work Planned for the Next Quarter.....	9
7. References.....	10
Appendix A.....	15

Interim Report No. 6
Corrosion and Creep Testing of Coated
Reinforcing Bars in Concrete

1. Project Information: Order No. 2-1-0614

Title: Nonmetallic Coatings for Concrete Reinforcing Bars

Date Project Initiated: September 17, 1971

Research Agency: National Bureau of Standards

2. Introduction

2.1 Background: The early deterioration of the concrete of bridge decks, attributed to the corrosion of the steel reinforcing bars, has become a major problem in highway maintenance during the past decade. The annual cost of repairing these damaged bridge decks is over 70 million dollars according to estimates of the Federal Highway Administration.

The corrosion of the steel reinforcement is caused by chloride ions from the two major deicing materials, sodium chloride and calcium chloride. Chloride ions depassivate steel thereby promoting the active corrosion of the steel.

A reasonable method to obviate the rapid corrosion of the reinforcement is to protect the bars with barrier-type of coating. The present study was undertaken to ascertain the feasibility of using organic coatings, especially epoxy systems, to protect steel reinforcing bars.

2.2 Objectives: To investigate the protective qualities of organic coatings, especially epoxy systems, and to select the most promising materials. The selection is based upon physiochemical testing with consideration given to economics involved in coating and fabrication.

3. Discussion of Activities

3.1 Corrosion Studies of Coated Reinforcing Bars Embedded in Concrete.

The protective qualities of epoxy and polyvinylchloride coating materials have been previously assessed by partially immersing coated reinforcing bars in aqueous solutions of 0.5 to 1.0 N NaCl. Performance of the coatings was evaluated by measuring both the electrical potential of the coated bar and the electrical resistance of the coating film. Many of the coatings adequately protected the reinforcing bars limiting corrosion to only a few isolated sites [1]. Because these coatings may behave differently when in concrete the present corrosion study was undertaken. Coated reinforcing bars embedded in concrete specimens similar to those described by Stratfull [2,3], have been partially immersed in an aqueous solution containing chloride ions. Any corrosion occurring is being monitored by taking both electrical potential and resistance measurements. The fabrication of test specimens and the method of testing are described in the following discussion.

3.1.1 Materials and Fabrication of Test Specimens

The materials and methods used to fabricate the corrosion test specimens were more thoroughly discussed in the previous report [4] and are summarized in this report to give a complete discussion of the tests.

The corrosion test specimens, figure 1, are concrete blocks, $2 \frac{7}{8} \times 4 \frac{7}{8} \times 15$ inches, in which are embedded a reinforcing bar concentric with the longitudinal axis of the block.

The mix proportion of the concrete was approximately 1:1.7:2.5 by weight of portland cement (type III), sand and coarse aggregate, respectively. The sand was a siliceous aggregate and the coarse aggregate was crushed stone. Maximum size of the coarse aggregate was $\frac{3}{4}$ inch. Water content of the concrete was about 5 $\frac{1}{2}$ gallons per sack of concrete and the slump ranged from 3 to 5 inches.

Coating materials were applied by the applicators or manufacturers handling the respective coatings, to No. 6 reinforcing bars furnished by the National Bureau of Standards. Surfaces of the bars were blasted to a white finish [5], coatings applied and cured, and then the bars were returned for testing [1].

The coated rebars selected for corrosion testing coincided essentially (when sufficient specimens were available) with those used in the pullout tests [4]. These coating materials and their application methods are described in table 1. The coating materials have been assigned code numbers for laboratory identification purposes, with the numbering sequence indicating the chronological order in which the materials were received.

The corrosion-test specimens were cast in wooden forms, which were lined with stripping oil, with the reinforcing bar in a horizontal position. The specimens were removed from the forms after 2 days, moist cured for 14 days, and stored at 50 percent relative humidity and 72°F until tested (60 days).

A terminal was inserted into an end of each reinforcing bar so that electrical connections could be made to a voltmeter or conductivity bridge. The other exposed end of the reinforcing bar was covered with a heavy coating, ca. 0.5 inch, of silicone sealant. Therefore, provided the silicone sealant does not leak, the reinforcing bars are exposed only to chloride ions permeating the protective layer of concrete.

3.1.2 Corrosion Test Methods

The corrosion-test specimens have been placed in a 105 gallon polyethylene-lined, fiberglass-reinforced, polyester tank, 4 ft. x 2 ft. x 2 ft. The bars are in a vertical position with the lower ends protected by silicone sealant fitted into 1 inch diameter holes drilled in 1 ft. x 1 ft. spacing racks of 3/4 in. thick marine plywood. The racks rest on a sheet of marine plywood laid on the floor of the polyester tank. Similar spacing racks have been placed on top of the specimens (figure 2). The marine plywood and racks have been coated with an epoxy paint to prevent their deterioration. Sufficient amount of a 3.5 percent sodium chloride solution was transferred to the tank to cover the lower 13 inches of each specimen, with the upper 2 inches of concrete being above the level of the solution.

Periodic measurements of electrical potential, millivolts (M.V.) vs. the saturated calomel half-cell (S.C.E.) and resistance (ohms), vs. the platinum electrode are being taken for each immersed specimen. The specimens also are being inspected regularly for visual evidence of cracking or other signs of failure. The tests will continue until either the concrete specimens have failed, as evidenced by cracking of the concrete, or the project is terminated. In the latter case, the concrete specimens will be split so that the condition of the coatings can be visually assessed.

3.1.3 Results and Discussion

The electrical potentials and resistances of the corrosion-test specimens are listed in table 2 for exposure periods of 24 and 1296 hours. The results obtained to date are in general agreement with the protective ratings given in table 8 of Interim Report No. 4 [1]. The large potential shifts noted for specimens 18, 30B, and 40-Phos A are attributed to sealing small holes in the silicone seals on the immersed portion of the reinforcing bars. NOTE: Some difficulty has been experienced with sealant failures. Efforts are being made to obtain more satisfactory sealants.

Electrical potential measurements do not seem to accurately indicate the corrosion state of the coated reinforcing bars. The uncoated bars have potentials of ca. -296 M.V. which are in the passive range [3], while many of the coated bars have much more active potentials. This same phenomenon was noted earlier in the corrosion testing of uncoated and coated bars immersed in 0.5 N NaCl [1], even though the uncoated bars were badly corroded as compared to little or no corrosion of the coated bars. It is felt the electrical potential measurements are not reliable indicators of the corrosion conditions of coated reinforcing bars.

Resistance measurements may possibly be more reliable indicators than potential measurements, since the resistance values are primarily dependent on the integrity of the coating films. The resistance of a film will sharply decrease if holidays develop or decrease more slowly if the film is deteriorating overall. The resistance of the protective

layer of water-soaked concrete is low [6,7], certainly much lower than the resistance of a good protective coating on a bar. The corrosion-test specimens giving the highest resistance measurements, listed in table 2, also generally had the highest protective ratings.

No evidence of cracks developing in the concrete cover nor of rust stains were observed.

3.2 Creep Tests

The work in the reporting quarter involved preparing the creep specimens and apparatus for testing. The creep specimens consist of a 4 ft. length of No. 6 reinforcing bar embedded in a 10 x 10 x 12 inch concrete prism so that the rebar is concentric with the longitudinal axis of the prism. The creep specimens are the same as the pull-out specimens described in a previous report [4].

3.2.1 Calibration of Springs

The 24 steel springs which will be used to exert tensile stresses of 15 and 30 ksi (30,000 psi), within the steel reinforcing bars, were calibrated. Dimensions of these springs are: height of 8 inches; outside diameter of 5/14 inches; and the steel coils have a diameter of 1 3/16 inches.

The springs were calibrated using the device (figure 3) shown in service in figure 4. The compressive displacement of the springs was measured with 1×10^{-4} in. micrometer dial gages. The load was exerted on the springs with a 60,000 lb. capacity hydraulic universal testing machine. Loads were in the range of 0 to 14000 lb. (14 kips) and dial gage readings were taken at intervals of 1 kip between 0 and 5 kips and 8 to 12 kips, while between 5 to 8 and 12 to 14 kips the intervals were 0.5 kips. Amounts of displacement were determined from the average values of two dial gages located diametrically opposite on the calibration device. The 24 springs

had nearly the same displacement response to loading as indicated by the plot in figure 5, which shows the range in displacement for corresponding load application.

3.2.2 Strain Gages

Strain gages, to monitor the tensional loads, are being attached to the reinforcing bars approximately 3 inches from the concrete prism. The gages, Model WK-06-500GB-350, were procured from Micro-Measurements, Romulus, Michigan^{1/}. These gages are reported to have only a small intrinsic creep of 10 M^{E} (microstrain units)/year and therefore should be satisfactory for the present study.

Sixteen of the 24 creep specimens have been instrumented with the strain gages and the remainder will be instrumented during April 1973. The methods that have been developed to attach the strain gages to the reinforcing bars are described in Appendix A.

3.3 Implementation

The NBS staff has assisted the FHWA in the implementation portion of the project by drafting preliminary performance specifications for powder epoxy coated reinforcing bars, which will be used in the construction of experimental bridges. In the early implementation phase the NBS staff also served as liaison between the FHWA and coating manufacturers and applicators.

^{1/} Certain materials are identified in this paper in order to adequately specify the experimental conditions. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards nor does it imply that the materials are necessarily the best available for the purpose.

3.4 Talks Based on Project

Talks based on the project have been given by Dr. James Clifton, before the following organizations:

1. Committee on Performance of Concrete-Chemical Aspects, Highway Research Board, January 22, 1973.
2. Committee on Corrosion. Highway Research Board, January 23, 1973.
3. NBS Composite Materials Seminar, February 1, 1973.
4. Research Session of the American Concrete Institute, March 7, 1973.

3.5 Meetings Attended

3.5.1 Meetings attended in conjunction with the project.

1. Highway Research Meeting in Washington, D. C., January 22 to 26, 1973, by Robert Mathey, Hugh Beeghly and James Clifton.
2. American Concrete Institute Annual Convention, Atlantic City, New Jersey, March 5 to 9, 1973, by James R. Clifton.
3. Epoxy Coated Reinforcing Steel Meeting sponsored by the Implementation Division of FHWA, February 21, 1973, Washington, D. C., by Hugh Beeghly, Robert Mathey and James Clifton.

3.5.2 Pertinent Meetings held between NBS Staff and Industrial Representatives.

1. Dr. Kiuchi of Republic Steel met with Hugh Beeghly on March 9, 1973.
2. Mr. Lang of H. C. Price met with Hugh Beeghly and James Clifton on January 8, 1973 at NBS.
3. Hugh Beeghly and James Clifton met with coating and engineering staff members of DuPont at Wilmington, Delaware on January 16, 1973.

4. Status of Project

Except for delays in starting the creep tests of coated and uncoated reinforcing bars, the project is progressing according to schedule. The delays in the creep tests are primarily due to modifications in instrumentation, especially in the type of strain gages. Revisions in plans by FHWA for loading and monitoring the creep specimens resulted in extensive changes in the instrumentation used to measure the tensile load in the steel rebars over a long period of time.

5. Problems

It is the opinion of the NBS staff that both the creep and corrosion testings of reinforcing bars embedded in concrete should be continued until either the specimens fail or unequivocal test results are obtained. This will necessitate continuance of these tests beyond the contract expiration date of September 30, 1973.

6. Work Planned for the Next Quarter

The remainder of the creep specimens will be instrumented and the creep tests will be commenced.

The corrosion testing of the coated and uncoated reinforcing bars embedded in concrete will be continued.

The following long-term studies will be completed:

- (1) Chloride permeabilities of thin epoxy films.
- (2) Corrosion testing of the coated and uncoated rebars in 3.5 percent aqueous NaCl.
- (3) Weight stabilities of epoxy discs immersed in several aqueous solutions.

References

1. J. R. Clifton, H. F. Beehly, and R. G. Mathey, Interim Report No. 4. Screening Tests for Evaluating Materials. National Bureau of Standards Report 10960, 1973.
2. D. L. Spellman and R. F. Stratfull, Laboratory Corrosion Test of Steel in Concrete, Research Report M & R 635116-3, Division of Highways, State of California, 1968.
3. R. F. Stratfull, Half Cell Potential and the Corrosion of Steel in Concrete, Research Report CA-Hy-MR-5116-7-72-42, Division of Highways, State of California, 1973.
4. J. R. Clifton, H. F. Beehly, and R. G. Mathey, Performance of Coated Steel Reinforcement in Concrete. Part 1. Investigation of Bond in Pullout Specimens, National Bureau of Standards Report, in Press.
5. Steel Structures Painting Council Surface Preparation Specification SSPC-Sp5-63, amendment 1971.
6. E. B. Rosa, B. McCollum and O. S. Peters, Electrolysis in Concrete, Technologic Papers of the Bureau of Standards, No. 18,(1919).
7. Adam M. Neville, Hardened Concrete: Physical and Mechanical Aspects, Chapter 18, Electrical Properties, American Concrete Institute Monograph No. 6, 1971.

Table 1
Long Term Corrosion Testing. Coatings on Reinforcing Bar
Specimens (No. 6 Coated Bars Embedded in Concrete)
Test Solution - 3.5% by Weight NaCl in H₂O

Coating Code No.	Quantity of Specimens	Coating		Application Method
		Type ^{1/}	Thickness (mil)	
1	2	Epoxy, liquid	5	Brush
1-1 ^{2/}	1	Epoxy, liquid	5	Brush
1-S ^{3/}	1	Epoxy, liquid	5	Brush
3	2	Epoxy, primer	3	Brush
4	2	Epoxy, liquid	25	Brush
18	1	Epoxy-coal tar, liquid	4	Brush
19	2	Epoxy, liquid	4	Dip & fused
25	1	Epoxy, powder	8	Electrostatic spray
27	2	Epoxy, powder	8	Electrostatic spray
28	1	Epoxy, powder	2	Electrostatic spray
29	2	Epoxy, powder	3	Electrostatic spray
30	2	PVC	17	Fluidized bed
31	2	Epoxy, powder	9	Electrostatic spray
38	1	Epoxy, powder	5	Electrostatic spray
39-Phos ^{4/}	2	Epoxy, powder	5	Electrostatic spray

Table 1 (continued)

Coating Code No.	Quantity of Specimens	Coating		Application Method
		Type ^{1/}	Thickness (mil)	
40-Phos ^{4/}	2	Epoxy, powder	5	Electrostatic spray
40	2	Epoxy, powder	5 2	Electrostatic spray
41	2	Epoxy, powder	3	Electrostatic spray
Uncoated	2	-	-	--

^{1/} Unless otherwise indicated, coating material was applied to rebars with surfaces blasted to a white finish.

^{2/} Same material as No. 1 but with different pigment.

^{3/} S denotes coating material No. 1 mixed with sand.

^{4/} Phos. indicates that the blasted steel surfaces of the rebars were phosphatized before the coating materials were applied.

Table 2

Electrical Potential and Resistance Measurements
of Corrosion-Test Specimens in 3.5 Percent NaCl.

Exposure Time (Hour)						
Coating Code No. <u>1</u> /		24		1296		Protective Rating <u>2</u> /
		EMF (MV)	Resistance (ohms)	EMF (MV)	Resistance (ohms)	
1	A	345.0	3.8×10^2	310.5	3.8×10^2	3
	B	408.8	7.0×10^2	335.3	8.6×10^2	
1-1		337.0	2.5×10^2	279.0	2.3×10^2	
1-S		484.5	4.8×10^2	449.0	5.1×10^2	
3	A	285.6	3.1×10^2	311.7	2.9×10^2	3
	B	260.3	2.7×10^2	281.7	2.9×10^2	
4	A	339.2	2.4×10^4	304.5	2.2×10^4	3
	B	130.0	1.0×10^5	148.4	1.3×10^4	
18		575.6	6.0×10^3	040.0 ^{3/}	1.1×10^4	3
19	A	484.0	5.6×10^2	406.5	5.1×10^2	2
	B	438.0	6.1×10^2	429.0	6.6×10^2	
25		542.7	4.1×10^2	408.5	4.4×10^2	1
27	A	654.6	1.3×10^4	638.7	1.8×10^4	3
	B	571.5	6.8×10^3	569.0	5.4×10^3	
28		461.5	5.2×10^2	460.0	4.4×10^2	3
29	A	376.3	6.4×10^2	377.7	6.6×10^2	2
	B	403.4	6.6×10^2	408.0	5.2×10^2	
30	A	058.0	1.0×10^5	059.0	1.1×10^5	1
	B	448.2	1.5×10^5	007.0 ^{3/}	1.7×10^5	
31	A	359.8	1.5×10^3	437.2	1.2×10^4	1
	B	092.2	9.8×10^3	043.5	6.5×10^4	
38		392.7	3.2×10^2	261.0	3.5×10^2	3

Table 2 - continued

Coating Code No. ^{1/}	EMF (MV)	Resistance (ohms)	EMF (MV)	Resistance (ohms)	Protective Rating ^{2/}
39-Phos A	513.0	4.9×10^2	396.3	4.5×10^2	3
B	536.2	5.0×10^2	401.5	4.2×10^2	
40-Phos A	282.2	2.5×10^2	127.7 ^{3/}	2.6×10^2	2
40-Phos B	382.5	3.4×10^2	386.2	3.1×10^2	
40 A	431.8	2.9×10^2	408.4	3.6×10^2	3
B	377.0	2.8×10^2	331.2	2.7×10^2	
41 A	540.5	6.0×10^3	532.8	1.2×10^4	2
B	575.9	5.4×10^2	547.6	1.2×10^4	
Uncoated A	334.2	2.7×10^2	291.7	2.3×10^2	4
B	264.0	2.6×10^2	299.0	2.7×10^2	

^{1/} A and B denote duplicate specimens.

^{2/} Ratings from Table 8 of reference [1].

^{3/} Large shifts in electrical potential attributed to sealing small holes in the silicone seal.

Appendix A

Methods of Attaching Strain Gages to Reinforcing Bars

A. Surface Preparation

- I. The area of the bar to be cleared of deformation patterns will start 1 3/4" from the surface of the concrete block and extend to 4 3/4" from the block, thus leaving a 3" length by 1/2" wide strip of smooth metal. On dummy and temperature compensating bars, center the area lengthwise on the bar.
- II. First use a coarse file to remove most of the deformation patterns.
- III. Next use a fine file to smooth the bar being careful not to remove any more metal than necessary.
- IV. Finally, round the surface with 80 grit closekote aluminum oxide.
- V. Degrease the area with either Chlorothene NU or Freon TF^{1/}
- VI. Final abrading of the surface is done with 320 grit silicon carbide paper after thoroughly wetting the smoothed area with M-Prep Conditioner A. When done, slowly wipe the surface dry with a gauze sponge.
- VII. Repeat VI.
- VIII. Apply alignment marks indicating where the gages will be located as needed with a ballpoint pen, carefully, so that the gages will be placed diametrically opposite on the rebars. DO NOT SCRIBE THE METAL!

^{1/} Certain materials listed in Appendix A are those suggested by the manufacturer of the strain gages and are identified in order to adequately explain the method of attaching the gages. In no case does such identification imply recommendation by the National Bureau of Standards nor does it imply that the materials are necessarily the best available for the purpose.

Appendix A - continued

- IX. Repeatedly apply M-Prep Conditional A and scrub with a cotton tipped applicator until a clean applicator is no longer discolored. Remove all residue and M-Prep Conditioner A by slowly wiping with a gauze sponge until the surface has no residues left.
- X. Apply a liberal amount of M-Prep Neutralizer 5 to the area and scrub with a cotton tipped applicator. With a single slow wiping motion of a gauze sponge, carefully dry the surface. Caution - DO NOT wipe the gauze back and forth as this may allow contaminants to be redeposited.
- XI. Slip meter support and measuring bars over the rebar and fasten as close to the concrete block as possible.

B. Strain Gage and Terminal Strip Attachment

- I. Using tweezers, remove the gage from its acetate envelope, cut leads to 1/4" and check with ohm meter. Place it, bond side down, onto a chemically clean glass plate. The terminal strip should be positioned next to it as the complete assembly will appear on the bar. While holding the gage in position with an acetate envelope, place a short length of Mylar JG tape over about half of the gage and the entire terminal strip.
- II. Remove the taped assembly by peeling the tape at a shallow angle (about 30°) and transferring it onto the specimen making sure that alignment marks coincide with specimen layout lines. If misalignment does occur, lift one end of the tape at a shallow angle until assembly is free. Realign and replace.

- III. Mix the 610 adhesive. Pour the contents of one "Curing Agent" bottle into one "Part A" dispenser bottle with the aid of the disposable plastic funnel. After replacing the brush-cap, shake the bottle vigorously for 10 seconds. Allow the mixed bottle to stand at least one hour before use. This mixed bottle of adhesive has a shelf life of about six weeks at 75°F. One bottle should last for many applications of gages.
- IV. Peel back one end of the taped assembly (again, at a shallow angle) so as to raise both the gage and terminal. By curling the Mylar tape back upon itself it will remain in position, ready to be accurately relaid after application of the adhesive. Install both gages before going on to the next step.
- V. Coat gage backing, terminal backing and specimen surface with a thin layer of adhesive. DO NOT allow adhesive applicator to touch tape mastic. Permit the adhesive to air dry for 5 to 30 minutes (at 75°F and 50% relative humidity).
- VI. Replace gage/terminal assemblies to their original positions over the layout marks using only enough pressure to allow the assembly to be taken down. Overlay gage/terminal areas with a piece of thin Teflon sheet. If necessary anchor Teflon in position with a piece of Mylar tape.
- VII. Cut a 3/32" thick silicone gum pad and a metal back up plate to a size slightly larger than the gage/terminal areas and carefully center these on the assembly areas. Clamp silicone pads and metal plates to the rebar..

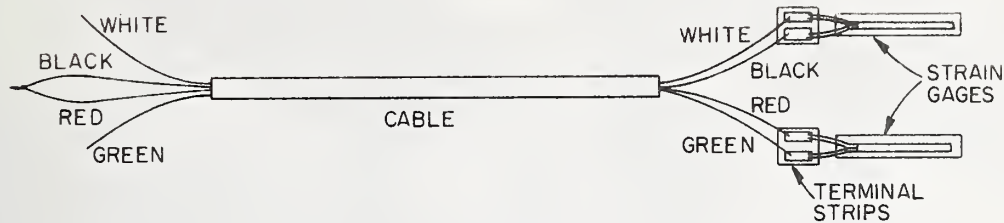
C. Curing

- I. Tip the specimen into an upright position, if not already. Slide the wire screen cylinder over the rebar and down until it rests on the concrete block.
- II. Wind the heating tape around the outside of the screen cylinder. Plug the heating tape into a variac in order to regulate the temperature.
- III. Slide the thermocouple in between the rebar and the screen to monitor temperatures. The thermocouple should be as close as possible to the rebar. Wrap the entire assembly with two layers of aluminum foil and gather loosely at the top.
- IV. Raise the temperature at the rate of 5°F to 20°F per minute up to a maximum of 350°F to 400°F. Allow the specimen to cure for 1 1/2 hours. Next, decrease the temperature to about 150°F-250°F and continue to cure for 2 more hours.
- V. Upon completion of the above curing cycle, turn off the heating tape and allow the temperature to drop to room temperature before removing the heating assembly, clamping assembly and tape.
- VI. After removing all tape, etc. wash the entire gage area with toluene in order to remove all mastic residue and other contaminants. Wipe dry with a gauze sponge.

D. Wiring

- I. Each lead wire must be exactly the same length; in the present case 30" long.
- II. Both ends of the 430-FST four wire cable will have the shielding and outer coating of Teflon stripped 2" back from the end of the cable. Each wire (red, black, white and green) will be stripped 1/4" on both ends.

III. Wiring diagram



IV. Solder the cable to the terminal strip using a small amount of rosin core solder and heat. Tape the cable to the rebar about where the shielding ends with black plastic electrical tape. Next, solder the strain gage leads to the terminal strip leaving them looped up, again using just enough solder and heat. Take the black and red leads at the output end of the cable, twist together and solder. This pair of wires should be folded back against the cable and taped down with black plastic electrical tape making sure the ends are covered.

V. Check wiring with ohm meter. Look for excessive resistance caused by faulty solder connections.

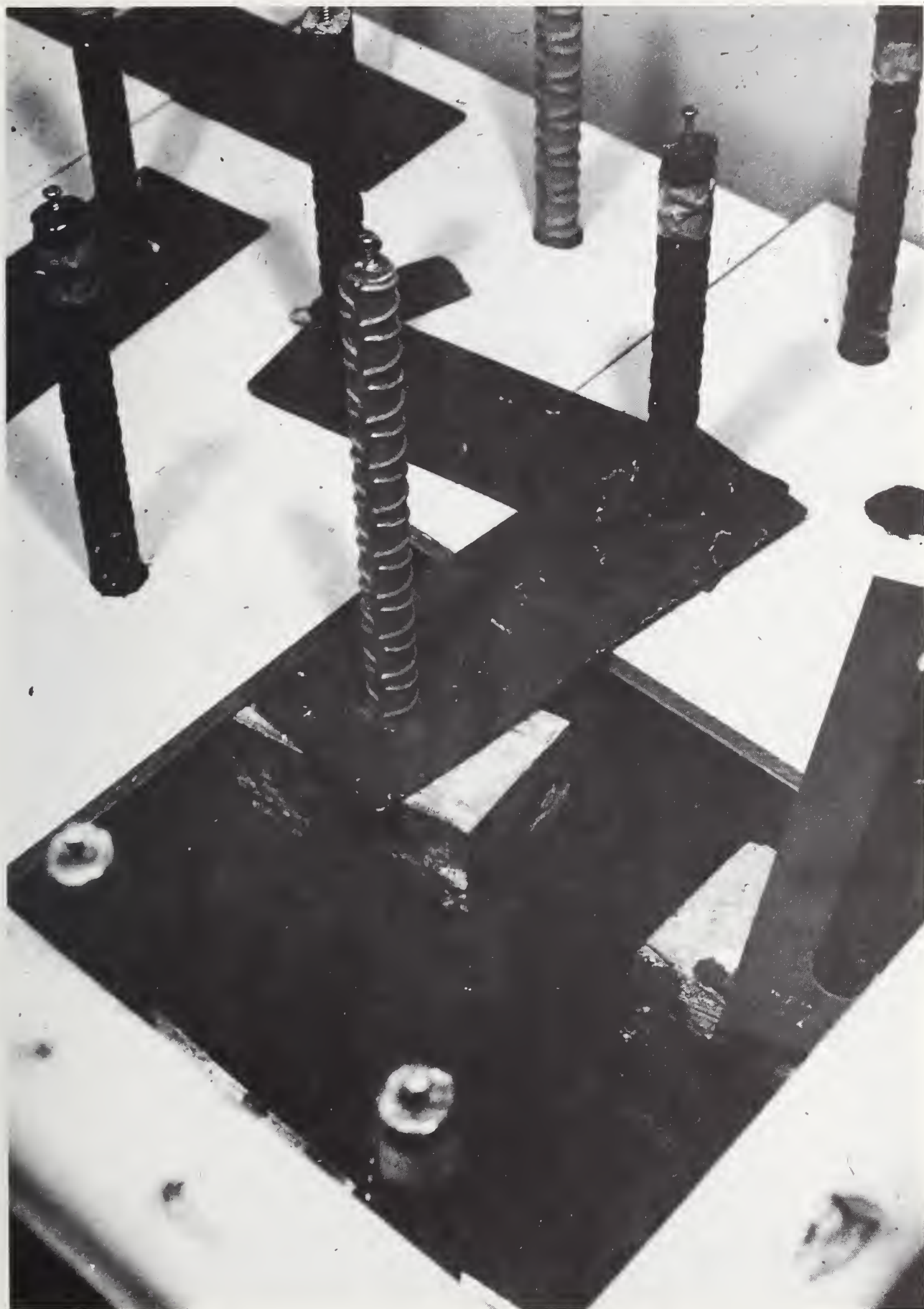
E. Coatings

I. Melt micro-crystalline wax (M-Coat W-1) and brush a thin layer (1/16") over the gage and terminal strip, and complete around the rebar.

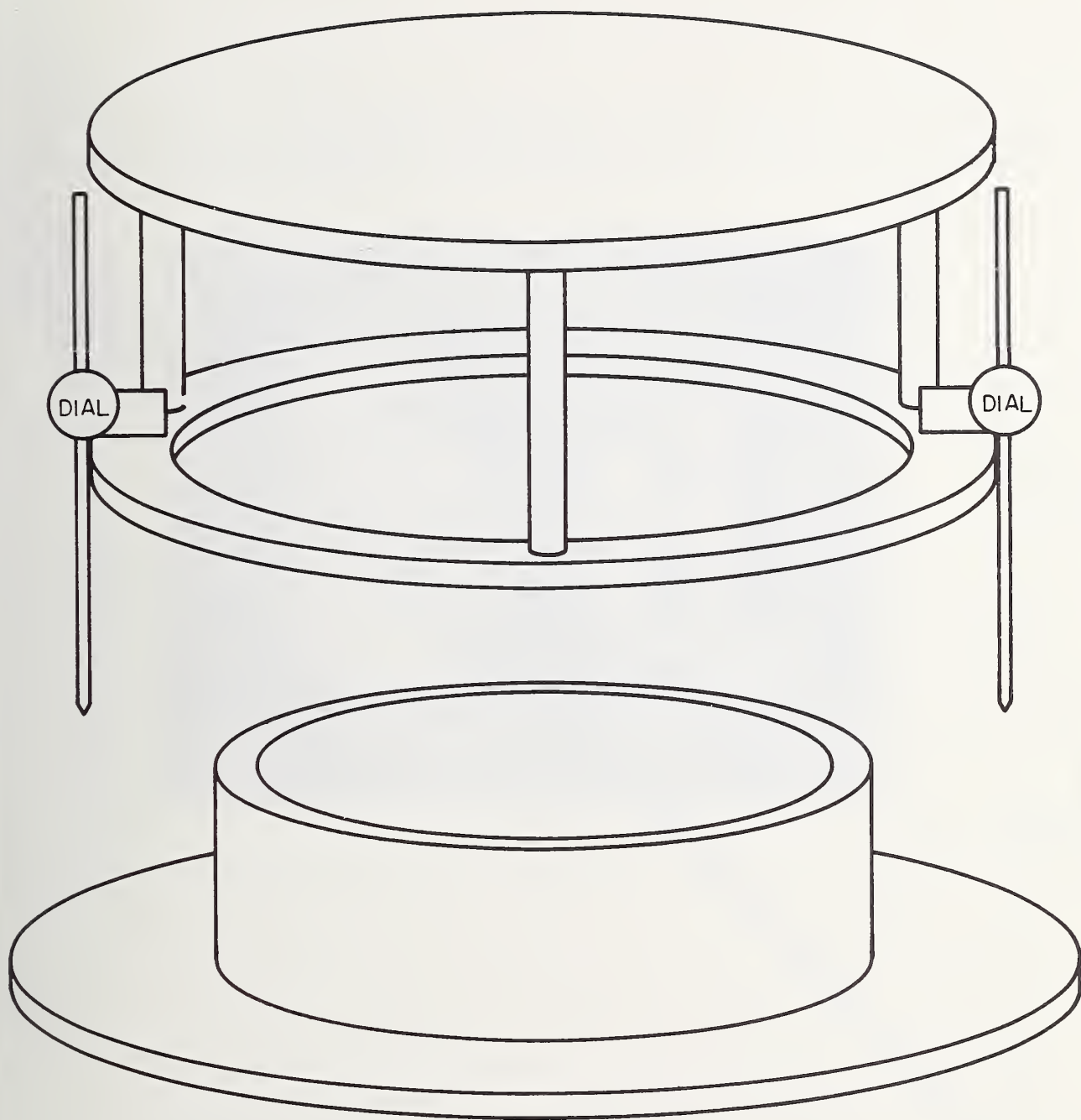
II. Mix and apply a coating of M coat G making sure that all the wax is covered. Allow to dry for 24-48 hours.

Captions for Figures

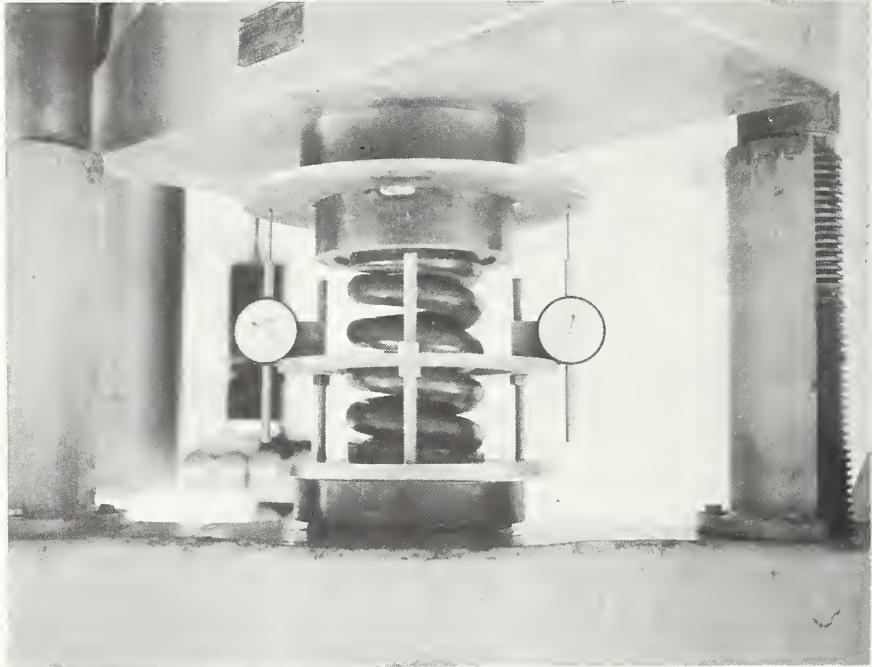
1. Coated Reinforcing Bar Embedded in Concrete-Corrosion-Test Specimen.
2. Corrosion-Test Specimens Immersed in 3.5 Percent NaCl.
3. Apparatus for Calibrating Steel Springs.
4. Calibration Apparatus with Spring Loaded in Hydraulic Testing Machine.
5. Range of Displacement Response of 24 Steel Springs.

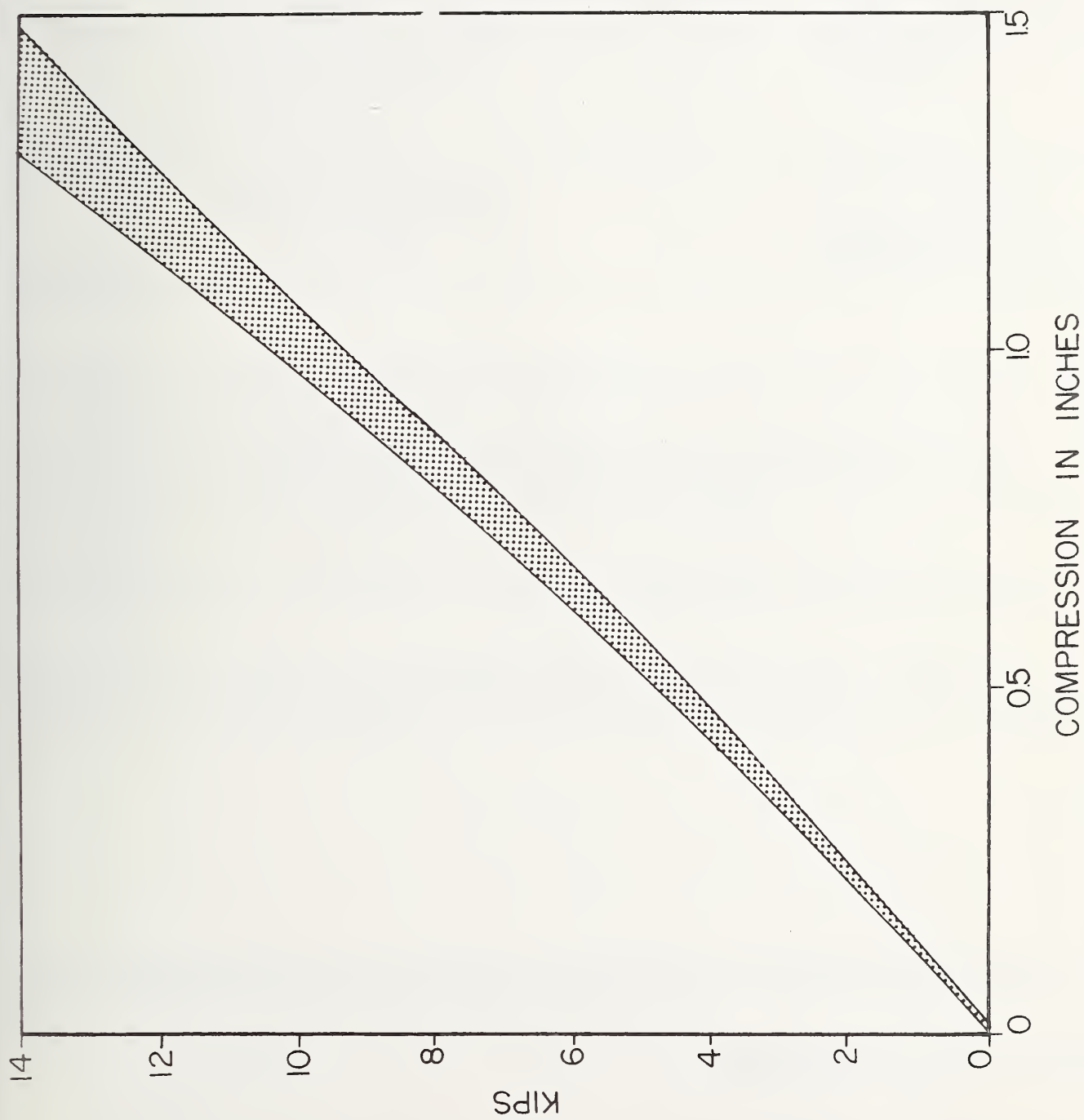






SPRING CALIBRATION APPARATUS





U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 73-229	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Interim Report No. 6. Corrosion and Creep Testing of Coated Reinforcing Bars in Concrete Nonmetallic Coatings for Concrete		5. Publication Date	
		6. Performing Organization Code	
7. AUTHOR(S) James R. Clifton, Hugh F. Beehly, Erik Anderson, Robert G. Mathey		8. Performing Organization NBSIR 73-229	
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234		10. Project/Task/Work Unit No. 4616433	
		11. Contract/Grant No.	
12. Sponsoring Organization Name and Address Federal Highway Administration U. S. Department of Transportation Washington, D. C. 20590		13. Type of Report & Period Covered Interim Jan. - Mar., 1973	
		14. Sponsoring Agency Code	
15. SUPPLEMENTARY NOTES			
<p>16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)</p> <p>The possibilities of protecting steel reinforcing bars embedded in concrete from corrosion by using organic barrier-type coatings are being investigated in this project. This corrosion is accelerated by the chloride ions of the two most commonly used deicing materials, calcium chloride and sodium chloride.</p> <p>In this report, corrosion studies carried out on coated reinforcing bars embedded in concrete are discussed. Methods of instrumenting creep-test specimens are also explained.</p> <p>The electrical potentials of coated reinforcing bars are not reliable indicators of the corrosion state of the steel bars. The electrical resistances of the coating films are more reliable indicators of the performance of a coating material than the electrical potential measurements.</p>			
17. KEY WORDS (Alphabetical order, separated by semicolons) Corrosion; creep testing; epoxy coatings; polyvinylchlorides; strain gages; steel reinforcing bars			
18. AVAILABILITY STATEMENT <input type="checkbox"/> UNLIMITED. <input checked="" type="checkbox"/> FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.		19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PAGES
		20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price

